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Influence of mineral fertilization and thinning intensity on the fruit body production of epigeous fungi in an artificial spruce stand (*Picea excelsa* Link) in North-Eastern France

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SUMMARY

All sporocarps of epigeous higher fungi have been counted in a forest experiment (artificial Norway Spruce on a mesotrophic brown leached soil on silty loam) with four thinning intensities combined with two fertilization treatments (control or NPK). Among forty species found, six were abundant and showed significant response to the treatments: *Clitocybe dicolor*, *Clitocybe nebularis*, *Macrolepiota rhacodes*, *Lycoperdon gemmatum*, *Lepista nuda*, *Russula atropurpurea*. They have a great variety of response pattern to both factors.

One of them *(Macrolepiota rhacodes)* an excellent edible mushroom, is greatly enhanced by fertilization: 45 kg per hectare vs. 6 kg per hectare. Following a precedent study on *Lepista nuda* this result confirms that forest fertilization may be of economic interest by improving mushroom production, besides increasing wood production. These results may improve our knowledge of the ecology of the cited species.

KEY-WORDS: *Production - Fungi - Fertilization - Thinning.*

RÉSUMÉ

Tous les carpophores de champignons supérieurs épigées ont été dénombrés dans un dispositif expérimental (plantation d'Épicéa sur sol brun lessivé mésotrophe sur limon) combinant quatre intensités d'éclaircie et deux traitements fertilisants (témoin et NPK). Parmi les 40 espèces trouvées, 6 étaient abondantes et répondaient significativement aux traitements : *Clitocybe dicolor*, *Clitocybe nebularis*, *Macrolepiota rhacodes*, *Lycoperdon gemmatum*, *Lepista nuda*, *Russula atropurpurea*. Elles présentent une grande variété de réponse aux deux facteurs.

L'une de ces espèces *(Macrolepiota rhacodes)*, un excellent comestible, voit sa fructification fortement stimulée par la fertilisation : 45 kg par hectare contre 6 kg par hectare. A la suite d'une précédente étude sur *Lepista nuda*, ce résultat confirme que la fertilisation des forêts peut présenter un intérêt économique autre que l'accroissement de la production de bois en améliorant la production de champignons comestibles. Ces résultats peuvent contribuer à la connaissance de l'écologie des espèces citées.

MOTS-CLÉS : *Production - Champignons - Fertilisation - Éclaircie.*

INTRODUCTION

The influence of site conditions on the distribution of higher fungi is little known. It has been studied mainly by observations on natural sites, using the methods of phytosociology.

It exists an other approach for a better understanding of the ecology of these fungi, making use of forest experiments (thinning, fertilization, weed control...) where some ecological factors are controlled and their influence on fungal fruit body production can be followed. MENGE & GRAND (1978) made such observations in three fertilization experiments on *Pinus taeda*.

In a previous investigation (GARBAYE *et al.*, 1979) this method was tested in a fertilizer experiment on several humus types, in a natural beech stand *(Fagus silvatica)* on an acid soil.

In this paper we present results of further observations in an artificial spruce stand *(Picea excelsa* L.*)* on mesotropic mull, with two controlled factors: thinning intensity and mineral fertilization.

These observations concern only one year and can only give preliminary results. Further observations on the same site are necessary to verify the preliminary results.

MATERIAL AND METHODS

The experiment was sited in north-eastern France near Nancy on loam and Keuper clay. The elevation was 375 m, with a very slight slope. The soil was a brown leached soil on silty loam with clay appearing at 50 cm. The humus type was a mesotropic mull. It had been slightly transformed under spruce by a 2-3 cm accumulation of needles.

The climate is intermediate between the atlantic and the continental, with 750 mm of total precipitation per year.

The artificial spruce stand was 38 years-old when the observations were made, with a basal area of 44 m² per hectare, and a dominant height of 21 m in the control plots (class 2 of the yield table of DECOURT, 1973).

At age 30 (8 years before the observations), two types of treatments had been applied:

— *thinning intensity:* the details of the four treatments are given in table I;

— *mineral fertilization:* there were two treatments: control and complete fertilization (150 kg per hectare of N as ammonium nitrate, 200 kg per hectare of P_2O_5 as superphosphate, and 200 kg per hectare of K_2O as potassium sulphate). The same amount of nitrogen was also applied the following year.

Individual plots were 0,1 ha, and the experimental design was full blocks, four replicates, split-plot type, with thinning intensity as principal factor.

TABLE I

Detail of the thinning treatments (medium and slight thinning are usual in the region).

Treatment	Per cent of basal area left after thinning: Winter 1970-1971	Winter 1976-1977
Vigourous thinning	62	60
Medium thinning	71	70
Slight thinning	81	80
No thinning	100	100

In each plot the total number of sporophores of each epigeous fungus, excluding those growing on stumps or decaying wood, was determined on three dates during 1978: August 28th, September 22th and October 13th. An early species *(Macrolepiota rhacodes)* was also counted on July 28th, and its total fresh weight per plot was determined. All counts were made during the same day, in order to avoid errors with fast growing species. Numbers of the two late edible species *Lepista nuda* and *Clitocybe nebularis* are probably underestimated because of picking by uncontrolled amateurs, but *Macrolepiota rhacodes* was apparently not affected.

All the sporophore numbers given below are per hectare and represent the total of three dates (four in the case of *Macrolepiota rhacodes*). Variance analysis calculations were made on transformed datas ($\log_{10} n + 10$)).

The year following the counts, we have donc systematic observations of the humus in all plots, and we measured the thickness of the litter (L layer of the A_0 horizon) and the pH in water of the A_1 horizon.

RESULTS

We found forty species (table II), three of which we could not identify at species

TABLE II

List of the forty species.

Mycorrhizal fungi	*Saprophytic fungi*
Amanita muscaria L.	*Agaricus augustus* Fr.
Amanita rubescens Fr. ex-Pers.	*Agaricus silvaticus* Sch.
Amanita vaginata var. *grisea* Fr. ex-Pers.	*Agaricus silvicolus* Vitt.
Anthurus archeri (BK.) Fisch.	*Clitocybe cerussata* Fr.
Boletus subtomentosus L.	* *Clitocybe dicolor* Lange
Choiromyces meandriformis Vitt.	*Clitocybe ditopa* Fr.
Cortinarius sp.	* *Clitocybe nebularis* Batsch
Geastrum sp.	*Clitocybe odora* Fr.
Hygrophorus pustulatus Fr.	*Collybia butyracea* Bul.
Laccaria amethystina Bolt.	*Collybia dryophila* Fr.
Leucocortinarius bulbiger (A. S.) ex-Fr. Lange	*Collybia platyphylla* Pers.
* *Russula atropurpurea* Kromb.	*Collybia radicata* Relh.
Russula integra Sing.	*Hebeloma radicosum* Bul.
Russula olivacea Fr.	*Lepiota cristata* Bolt.
	Lepista inversa Scop.
	* *Lepista nuda* (Bull. ex-Fr. Cooke)
	Lycoperdon gemmatum Batsch
	Lycoperdon pyriforme Pers.
	* *Macrolepiota rhacodes* Fr. ex-Vitt.
	Mycena epipterigia Scop
	Mycena inclinata Fr.
	Mycena pura Pers.
	Mycena sp.
	Pluteus cervinus Sch.
	Stropharia aeruginosa Curt.
	Tricholomopsis rutilans Fr. ex-Sch.

* Abundant species.

level (*Cortinarius* sp., *Mycena* sp., *Geastrum* sp.). Forteen of these species are commonly considered as mycorrhizal. We found statistically significant differences between treatments (at the 5 % level) for six species, five of which were saprophytic species and one mycorrhizal. Figures 1 to 6 give the results for these six species and table III summarises the different significant responses to treatments (thinning and fertilization) at the 5 % level.

TABLE III

Significant response of six species to thinning and fertilization (0: no response; +: positive response; —: negative response at the 5 % level).

Species	Response to thinning	Response to fertilization	Interaction
Clitocybe dicolor	+	+	0
Clitocybe nebularis	+	—	—
Macrolepiota rhacodes	—	+	0
Lycoperdon gemmatum	+	0	0
Lepista nuda	—	0	0
Russula atropurpurea	—	—	0

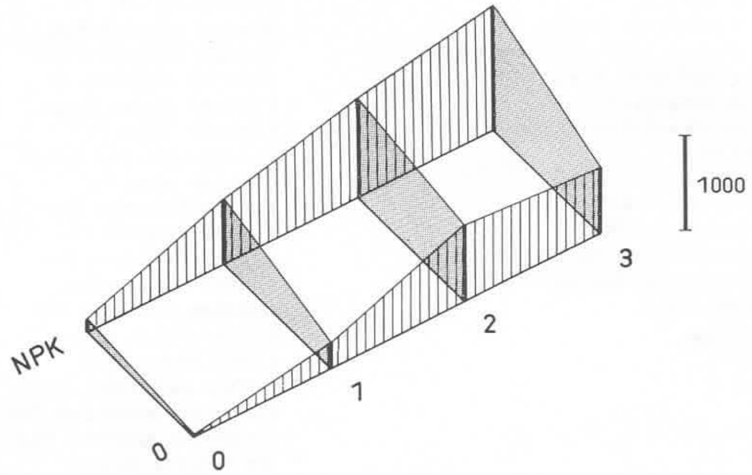

FIG. 1. — Distribution of *Clitocybe dicolor* Lange in relation to the treatments (number of sporophores per hectare). Fertilization treatments are indicated on the left (0: no fertilization; NPK: complete fertilization). Thinning treatments are indicated on the right (0: no thinning; 1: slight thinning; 2: medium thinning; 3: vigourous thinning). The vertical bar gives the scale.

The six species react to thinning, either positively or negatively. *Clitocybe dicolor*, *Clitocybe nebularis* and *Lycoperdon gemmatum* fruit bodies are much more abundant after strong thinning.

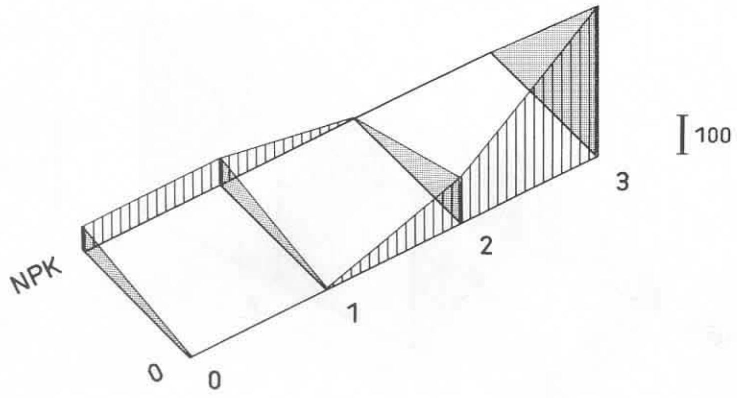

FIG. 2. — Distribution of *Clitocybe nebularis* Batsch in relation to the treatments. Same legend as figure 1.

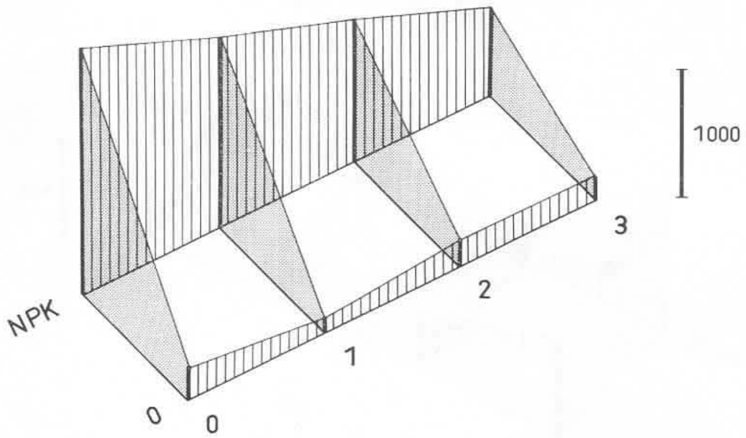

FIG. 3. — Distribution of *Macrolepiota rhacodes* Fr. ex Vitt. in relation to the treatments. Same legend as figure 1.

Inversely, *Lepista nuda*, *Macrolepiota rhacodes* and *Russula atropurpurea* fruit bodies are more abundant with no thinning.

Clitocybe dicolor reacts slightly positively to fertilization.

The number of *Macrolepiota rhacodes* fruit bodies is very highly enhanced by fertilization, mainly in the denser stands: total yield for July 28th, August 25th, September 22th and October 13th is 6 kg per hectare for non-fertilized plots, 15 kg per hectare for fertilized plots with strong thinning, and 45 kg per hectare (fresh weight) on fertilized plots without thinning.

Inversely *Russula atropurpurea*, which is a mycorrhizal fungus, disappears completely after fertilization. But we do not know whether the depressive effect of

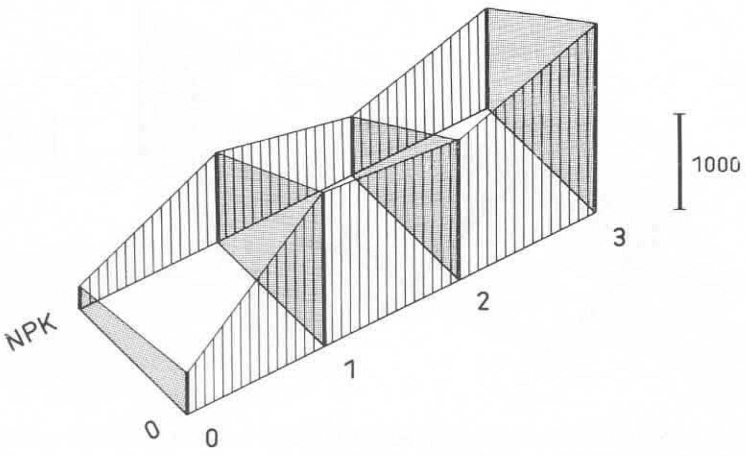

FIG. 4. — Distribution of *Lycoperdon gemmatum* Batsch in relation to the treatments. Same legend as figure 1.

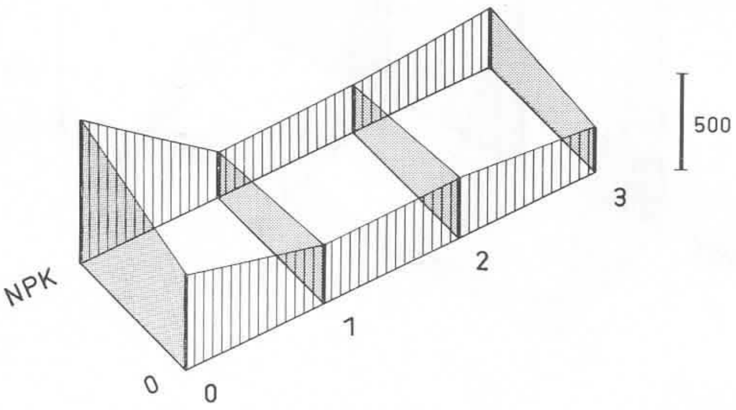

FIG. 5. — Distribution of *Lepista nuda* (Bull. ex Fr.) Cooke in relation to the treatments. Same legend as figure 1.

fertilization is only on fructification or also on the numbers of mycorrhizal roots.

One species *(Clitocybe nebularis)* shows an inteıaction between thinning and fertilization: fruit bodies appeared with medium and vigourous thinning, without fertilization, but their production was also increased by fertilization without thinning.

The thickness of the litter layer was very dependant on the treatments (fig. 7). It was less thick with vigourous thinning, mainly on non-fertilized plots probably because of lower meedle production and increased mineralization of the organic matter by light. The thinning treatments had no influence on the pH of the A_1 horizon, but fertilization lowered it from 4.6 to 4.4.

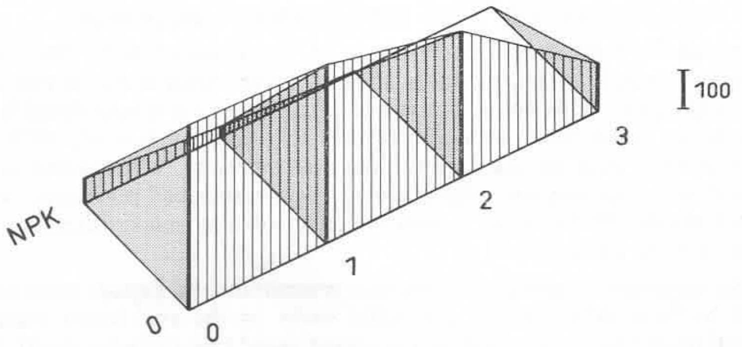

FIG. 6. — Distribution of *Russula atropurpurea* Kromb. in relation to the treatments. Same legend as figure 1.

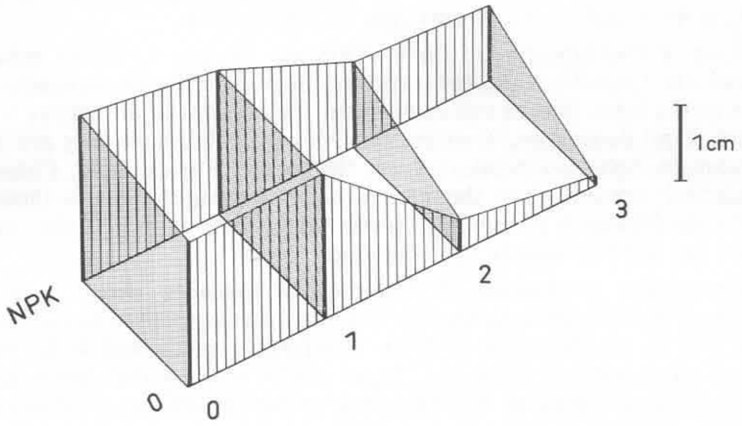

FIG. 7. — Thickness of the litter (L layer of the Ao horizon) in relation to the treatments. Same legend as figure 1.

DISCUSSION AND CONCLUSIONS

Some points require consideration in the interpretation of these results. Our counts were very limited in time, and we known that many species do not fruit every year, because of climatic conditions or inherent cycles. Meanwhile, we verified a relative stability of the results fo *Macrolepiota rhacodes*: the year before and the year after the present study, qualitative observation (without counting) have shown the same distribution of this species as a function of the treatments.

Moreover we completely ignored the hypogeous fungi, which may represent half of the total higher fungi of the site (FROIDEVAUX, SCHWÄRZEL, 1977). Finding no sporophores does not mean that the fungus is asbsent: mycelium or mycorrhizae may be present. If a treatment has an effect on fruit body production, this can be by direct effects on fungal physiology or by indirect effects on host physiology and the development of mycorrhizae in case of mycorrhizal fungi.

With these restrictions in mind, some conclusion are possible.

1) Among the forty species found, only 35 % are mycorrhizal. Only one mycorrhizal fungus, *Russula atropurpurea*, is affected by the treatments. It responds negatively to fertilization. This behaviour is not usual either for mycorrhizal fungi or for Russulae, as we know from the beech stand study (GARBAYE *et al.*, 1979) and from other unpublished data in oak stands *(Quercus petraea)*, where some mycorrhizal species as *Boletus chrysenteron* and *Russula lepida* responded positively. Meanwhile, MENGE & GRAND (1978) found a negative effect of nitrogen fertilization on *Suillus hirtellus* in a *Pinus taeda* stand.

2) Two saprophytic species, *Lycoperdon gemmatum* and *Lepista nuda* were greatly influenced by fertilization in our preceding study on the acid beech stand (humus: moder, mull moder and acid mull). In the spruce stand (mesotrophic mull) they do not react to fertilization, but they react to thinning. The soil is rich enough without any fertilization for optimal growth and/or fructification of these two saprophytic species. *Lycoperdon gemmatum* and especially *Lepista nuda* are naturally present on mesotrophic mull, but they do not exist or do not fructify on moder or acid mull, except when we modified the humus type by fertilization.

3) Three of the saprophytic fungi, *Clitocybe dicolor*, *Clitocybe nebularis* and *Lepista nuda* are typical « white rot » species, degrading brown polyphenol-proteins complexes of the litter. But in this experiment they do not at all behave in the same way toward stand density and fertilization. They probably have very precise optima for microclimate, light, temperature, litter thickness... For example, *Clitocybe nebularis* is essentially present where the litter is thinner (strong thinning without fertilization). *Clitocybe dicolor* is essentially present when there is more light, and *Lepista nuda* where the light is weaker (no thinning).

4) Sporophores production of *Macrolepiota rhacodes*, which is an excellent edible mushroom, is highly enhanced by fertilization (6 kg per hectare in fresh weight from July 28th to October 13th 1978 for non-fertilize plots, and 45 kg per hectare on fertilized plots without thinning). These results confirm that forest fertilization may be of economic interest by improving edible mushroom production besides increasing the wood production.

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